Traffic Modelling in WLANs and Cellular Networks

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***Abstract*—Over the past several years there has been a considerable amount of research in the field of traffic modelling for WLANs and Cellular Networks as well as the integration of these networks. To date, the focus of published work has been largely on the operation of delay sensitive calls. Because the voice calls are no longer the only service in wireless and cellular systems, multi-service traffic networks now consist of integrated services with distinctive Quality of Service (QoS) requirements. Therefore, a number of different schemes have been proposed to deal with this problem. Most of these schemes only consider mobility and multi-service traffic characteristics. However, few studies have considered the impact of buffering of voice calls in integrated voice and data services. Therefore, we aim to make a critical investigation of existing traffic models and offer generic traffic schemes for WLAN and Cellular networks in order to analyse the impact of buffering of voice calls in hybrid networks. For this purpose, an analytical model for performance evaluation of a single server network with voice and data traffic is considered. In this system, voice is given priority but can be buffered in a limited way. The analysis shows that this approach can be used in fast mobile systems.**

***Index Terms*—Analytical Modelling;Single Channel System;Multi-dimensional Markov process;integrated voice and data services**

I. Introduction

Traffic theory means the application of mathematical modelling to analyse the traffic performance in terms of network capacity and traffic demand considering QoS requirements [1]. Analytical Modelling solution techniques can be used to analyse the performance of traffic models to integrate services in the most appropriate way in order to ensure QoS requirements. The theory of stochastic processes can be employed to derive a mathematical model as traffic demand is statistical in nature. Therefore, performance must be denoted in terms of probabilities [1], [2]. Queuing networks and Markov chains are commonly used for the performance and reliability evaluation of communication systems. The relationship between QoS characteristics and traffic demand plays significant role in performance analysis. The main task for performance analysis is to ensure QoS requirements.

Some functional capability offered by a service provider to service users is defined as a service within the generic framework [3]. The overall effect of service performance which decides the level of contentment from the perceptual point of view of the service can be defined as Quality of Service (QoS) [4], [5]. In communication systems, service performance is closely related to network performance. Therefore, QoS models need to provide different priorities to multi-service flows in order to guarantee good performance [4].

The most important feature for next generation wireless networks is their ability to offer different classes of service; especially multimedia and real-time services in addition to the traditional telephony and data services. Providing QoS for the new services will require various alternative admission control algorithms and channel allocation schemes. Resource reservation policy can be used to give priority to real-time traffic over non-real traffic. Also buffers can be used in order to handle delay insensitive traffic so as to reduce packet drops and to maintain high link efficiency [6]. Since the volume of data traffic is growing faster than voice traffic because of scientific and industrial innovations such as the World Wide Web (WWW), e-commerce, and applications such as video conferencing or video streaming, a clear goal for the enterprise is to optimize the performance of networks to carry data, voice, and video traffic [7].

Integration of both types of real and non-real data on same links has significant advantages. An integrated system is a way to reduce the cost and take advantage of underused network capacity. The increasing demand for unified multimedia communication on a single IP Network has encouraged network designers of both service providers and enterprises to use integrated voice and data systems. Bringing together video with voice and text applications to create multimedia services is a significant development in the worldwide communication marketplace since it can provide many important opportunities. From a service provider's perspective, multimedia applications are used to attract new customers and increase the reliability of current ones while increasing revenue. Business can use multimedia to improve customer service and build up better employee communication in order to improve the worker productivity. Therefore, service providers are attracted by the lower cost model. Likewise, enterprise network designers are interested in direct cost savings associated with reduced maintenance costs and more efficient network control and management.

Voice over Internet Protocol (VoIP) allows both voice and data communication to be run over a single network, which significantly reduces infrastructure cost [8]. Until recently, Internet-based non-real-time data services are the main usage of the WLANs. However, the needs for real-time (RT) services such as VOIP and audio/video (AV) streaming over the WLANs have been increasing considerably; the use of 802.11

to transport delay sensitive traffic is becoming increasingly important. Therefore, it is significantly important to look at how best to tradeoff between buffering delay and loss for voice calls in integrated voice and data networks including the development of the recent 802.11e standard in order to ensure appropriate QoS.

Apart from the Internet, cellular networks have also seen an extraordinary growth in its usage. This results from the demand for multimedia applications. The second Generation (2G) cellular systems, which offered circuit-switched voice services, are now evolving towards third Generation (3G) systems that are capable of transmitting high-speed data, video and multimedia-traffic. Multimedia traffic is the transmission of data representing various media over communication networks. The future cellular network is named as fourth Generation (4G) network system which will run with the cooperation of 2G and 3G and also will communicate IP based wireless communication. Multimedia communication is now possible via the use of high bandwidth. The multimedia traffic requires transfer of large volumes of data at very high speeds, even when the data is compressed. Especially for interactive multimedia communication, the network must provide low latency. Because the IEEE 802.11 WLANs have been rapidly gaining popularity to provide high-speed wireless access for indoor networks, enterprise networks and public hotspots, service providers are looking to combine their existing cellular data service with WLAN as an alternative to provide high speed wireless data access in hotspot areas. Integration becomes a trend in current and future wireless networks, and in many cases results benefit both end users and service providers. Due to the changing conditions in wireless topology and possible mobility and characteristics of media traffic, providing seamless, anytime and anywhere, type of service is a challenging task for wireless systems in network communication. This is an inevitable result of technological improvement, popularity of cellular phones, and the growing range of multimedia applications.

There have been many existing traffic models proposed for the specific type of networks. However, we aim to look at generic traffic model that can be adapted to general network characteristics so as to look at mechanisms such as vertical handover, where the mobile node is moving amongst different networks. If the network is fast, queuing voice calls can reduce the blocking probability. Therefore, it is important to analyse the impact of voice calls over data calls in integrated systems.

The structure of this paper is as follows: In Section II, we first review existing traffic models for voice calls in hybrid network and also the integration of traffic characteristics and mobility. Following this, in Section III, we present the analytical models for a single channel system as well as a two channel system in order to explain generic traffic model. Detailed results from our analytical model are presented. In Sections IV further work is discussed and conclusions are summarized in Section V.

II. PREVIOUS WORK

A. Modelling for Queuing Systems for Voice

In [9], two types of traffic; real-time (voice /or video) and non-real-time (data) traffic flows are considered as a single multimedia stream. The authors highlight the necessity of considering the relationship between two types of flows within the same multimedia stream. Arrivals are described by the Batch Marked Markov Arrival Process (BMMAP) where the service time distribution is PH. The queue is finite and the corresponding queuing systems behavior is explained as multi-dimensional, continuous time, skip-free- to-the-left Markov chain. In most of the studies, in performance analysis of integrated systems, the Poisson process is used for the inter-arrival time of voice and data calls and exponential distributions are used for the service times of the channels [9]–[12].

A software upgrade-based approach was proposed to improve the VoIP performance over 802.11 WLAN in [13]. Dual queues on top of the 802.11 MAC controllers were implemented so as to queue the real time (RT) as well as non real time (NRT) packets into one of the two queues. The NRT queue is never served as long as the RT queue is non-empty since RT packets have strict priority over NRT packets. Because the behavior of TCP flow control in the WLAN, performance of VoIP can be enhanced using the scheme presented in this paper.

The proposed model in this paper considers modeling a single cell in a wireless network for different traffic behaviors and service requirements to attain the best trade-off. A homogenous wireless system is considered. The proposed models consider systems with finite as well as infinite queuing capacities. A single channel system is considered for both models in order to analyse the behavior of the channel with priority given to voice calls. The channel is assigned two different types of traffic; real-time (voice) and non-real-time (data) traffic flows. The model can be used for other single channel wireless cellular systems, or can be extended for systems with multiple channels.

B. Traffic Models and Mobility in Integrated Networks

The concept of handoff prioritization schemes based on exclusive channels reservation is to reserve a certain amount of channel to be used for handoff requests. In these schemes, new session requests have higher probability of blocking. However, it may be more convenient for micro-cellular networks where due to the small size of the network, the number of new calls will be reduced [14]. Guard channel schemes are used to hold handoff calls using some fixed or adaptively changing number of channels. The remaining channels are used by new and handoff calls [14], [15]. The main advantage of using such a scheme is to decrease forced termination probability in micro- or pico-cellular scheme. However, this causes an increase in originating call blocking probability as well as more congestion over total carried traffic [14], [15].

In addition to the guard channel scheme in [16], queuing of handoff attempts is allowed if necessary, however, no queuing of new calls is considered. To give priority to soft handoff calls, the idea of soft guard channels is introduced in [17]. Soft guard channels, similar to normal guard channels, reserve some traffic load exclusively for handoff calls. However, due to the limited interference of CDMA network capacity, the Call Admission Control (CAC) is distributed which the admission decisions are supported of both the local and the adjacent cells. Consequently in [17], the proposed algorithms can reduce the dropped calls significantly, while the blocked calls are increased at a relatively small rate under both homogeneous and hot spot traffic loads.

In [18], some existing vertical handover schemes are summarized. In WLAN-first handoff scheme (WFH), originating and data calls from the overlapping area are directed to the WLAN first, while ongoing voice and data calls are handed over to the WLAN if WLAN coverage and bandwidth are available. The main disadvantage of this scheme is to treat voice or data horizontal and vertical handoff call in the same way. A multi-hop ad-hoc relaying handoff (MARH) is employed for the vertical handoffs from WLAN to the cellular network. To implement the proposed method, practical routing protocols are needed which increase transmission delay due to the implementation complexity.

Handover schemes for multi-service traffic mainly include channel borrowing schemes, channel reservation and queuing [19]. To increase the priority of real time handover, a channel borrow scheme is proposed. Such a scheme only allows real time handover calls to access the borrowed channels.

Integrated service-based handoff (ISH), integrated service-based handoff with queue capabilities (ISHQ) with vertical handoff schemes were proposed respectively in [18]. Compared with existing handoff schemes in integrated cellular and WLAN networks, the proposed schemes take into consideration a comprehensive set of system characteristics such as voice and data services, user mobility and vertical handoffs especially in two directions from WLAN to Cellular and Cellular to WLAN. Therefore, it was shown that the proposed ISHQ scheme in Cellular/WLAN networks performs better QoS provisioning for voice and data in order to maximize the utilization of overall bandwidth resources.

Although the improvements of system performance are dependent on queue size in [18] for multi-services handover schemes, the impact of buffering of voice calls which is the focus of our study was not taken into account. Moreover, to obtain realistic composite performance with failure and recovery behavior, it is also important to evaluate the availability of multi-service systems [8].

III. TRAFFIC MODELLING

A. SINGLE CHANNEL SYSTEM

The proposed single channel model considers modeling a single channel wireless network for different traffic classes and service requirements to attain the best trade-off. A single channel homogenous wireless system is considered with capacity to buffer voice and data calls with priority given to

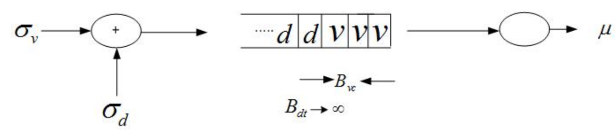

Fig. 1. The model of the system with infinite buffering.

voice calls. The channel is assigned to two different types of traffic; real-time (voice) and non-real-time (data) traffic flows.

In order to prevent data loss for the proposed model, queuing capacity for data calls has been assumed to be infinite, while the buffering for voice is small. Although the given model can easily be solved for finite capacity queues for data calls, it is possible to assume infinite queuing capacity in order to investigate the response times for data calls, while the priority is given to the voice calls as shown in Fig. 1. The proposed model has Markov processes the arrival and departure of voice as well as data calls, where voice and data call requests share a common queue.

The maximum number of voice calls allowed in the system is equal to one voice call assigned to the channel in the system plus the queuing capacity. The maximum number of voice calls in the system is given by the buffer for voice call, L_{vc}, as shown in Fig. 2. Voice calls arriving at a mean rate of σ_v when this rate is σ_d for data calls. Data calls cannot be lost but can tolerate some delay or jitter [20]. The number of data calls accepted in the system is equal to one data call being serviced plus queuing capacity. The maximum number of data calls in the system is given by L_{dt}.

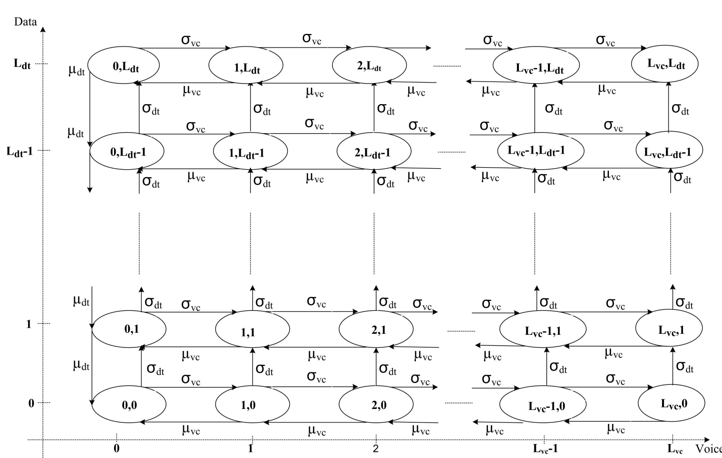

Fig. 2. State transition diagram for single channel system.

Fig. 3 shows the blocking probabilities and response time of voice calls as a function of L_{vc} for different σ_v values. The results show that as the queuing capacity of voice calls increases, the blocking probability of voice calls decreases significantly and is within acceptable ranges where response time is less than 100 ms. Since we give priority to voice calls, the blocking probability decreases when the queuing capacity of the voice calls is increased. The applications with voice call requests can tolerate blocking probabilities which are less than 0.01 [8].

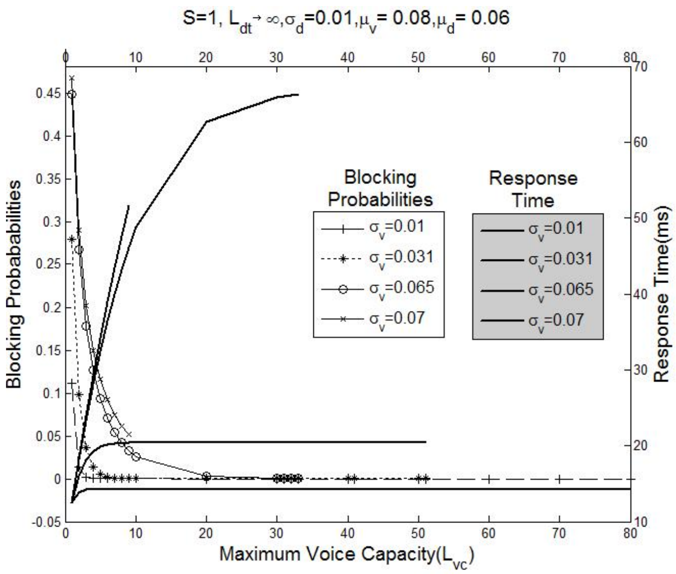

Fig. 3. Blocking Probability and Response Time as function of L_{vc}.

The impact of buffering of voice calls over data calls is analysed when the arrival rate of data calls arriving at a mean rate of, σ_d, is increased. When the arrival mean rate, σ_d, is around 0.03, the system started to experience response with higher delays due to the nature of single channel system and priority given to the voice calls. The results in Fig. 4 shows that single channel system performance is affected significantly when there is a heavy load of data calls in the network.

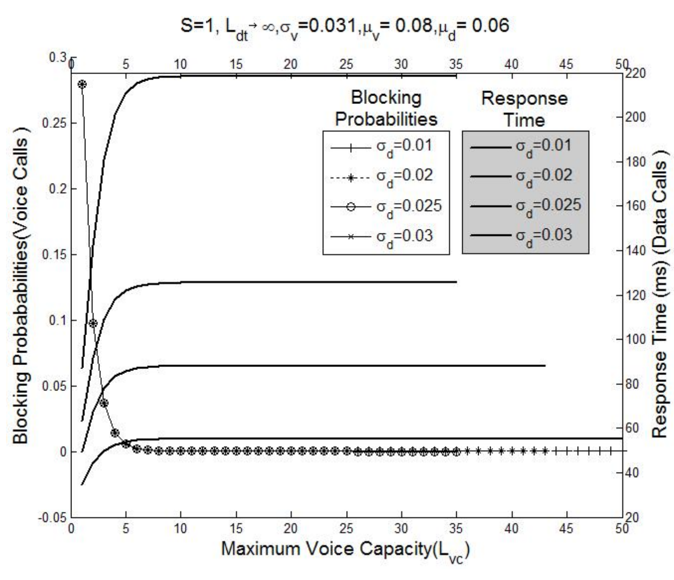

Fig. 4. Blocking Probability of voice calls and Response Time of data calls as a function of σ_v.

B. MULTI-CHANNEL SYSTEMS

Multi-channel systems and the services they will provide such as voice, data and e-mail are sometimes difficult to model. Much of the difficulty in developing analytical model comes up due to the mobility of network users, especially the handovers (handoff) required by such users. The users in next generation wireless networks are expected to be mobile user. Therefore, the effects of user mobility on system performance are a central issue for the design and implementation of mobile networks. Hence, both user mobility and multimedia traffic characteristics have to be taken into account in order to developed Quality of Service (QoS) framework. Beside the regular latency requirement, both minimizing the dropping rate of handoff calls and controlling the blocking rate of new calls play significant role to provide guarantee QoS for multimedia traffic in integrated system.

Since mobility is the most significant feature of a wireless cellular communication system, poorly provided handoff schemes cause a sudden decrease in QoS. In order to overcome this problem, many traffic models have been introduced based on different assumption about mobility. However, as we discussed in the single channel system, we first have to take into account the impact of buffering of voice calls in a multi-channel system and find the limitations of network characteristics for the generic traffic model. Therefore, we have started by looking at a simple multi channel system (C=2) without considering mobility issue as shown in Fig. 5. Once the system is solved using two channel scheme, we will then generalise the solution for multi channel systems.

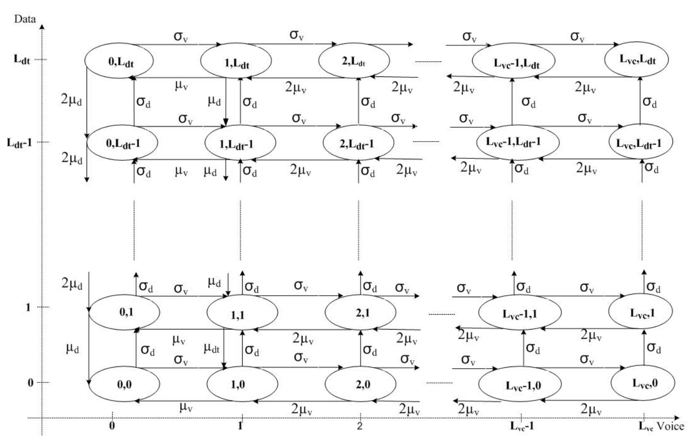

Fig. 5. State transition diagram for two channel system.

IV. FUTURE WORK

The next generation mobile wireless networks will give the end-user a greater choice of access technologies, and therefore, the decision to select the best interface. Hence, the proposed model with multi-channel support will be used to model cellular networks in order to find the limitations of network characteristics to ensure QoS services. As we discussed in the previous work section, mobility has a significant effect on user performance. Therefore, once the generic traffic model is ready, we will integrate the traffic and mobility models

V. CONCLUSION

The results show that the proposed models can be used for the optimisation of the performance of a given network. As the queuing capacity of voice call increases, the blocking probability of voice call decreases significantly to acceptable ranges where the response time is much less than 100 ms. Since we have given priority to voice calls, the blocking probability decreases when the queuing capacity of the voice calls is increased.

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